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SAFETY EVALUATION OF "PHOTO FINISH"

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Li/SO_2 batteries are used to provide power for an air deployable expendable store "Photo Finish". This report presents results of a test program to determine if the system is safe for fleet use.

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FOREWORD

Li/SO_2 batteries are used to provide power for an air deployable expendable store "PHOTO FINISH". This report presents results of a test program to determine if the system is safe for Fleet use.

Approved by:

JACK R. DIXON, Head
Materials Division

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CHAPTER 1

INTRODUCTION

A technical evaluation and safety analysis has been conducted on an air-deployable expendable store "PHOTO FINISH". The purpose of this report is to describe the results of a test program requested by NAVELEX (as required by reference 1) and conducted by the Naval Surface Weapons Center. The tests were conducted to determine if the unit was safe to handle, ship, and deploy as configured.

Abuse conditions were generated by:

1. Simultaneous short circuiting of the batteries with all fuses bypassed.

2. Simultaneous discharge of each battery pack into voltage reversal with an external D.C. constant current power supply. Discharge currents were equal to the fuse value of each battery in the pack.

3. Heating of the batteries to 500°C at a rate of 20°C/min.

"PHOTO FINISH" is composed of four separate batteries described below:

1. Battery number one has thirteen L026SH lithium sulfur dioxide cells wired in series.

2. Battery number two has four L026SH lithium sulfur dioxide cells wired in series.

3. Batteries three and four each have two L032S lithium sulfur dioxide cells wired in series.

All cells used in this test program were manufactured by Duracell International, Inc.

Batteries one and two each have a thermal fuse (80-90°C) and a four ampere fuse in the ground leg. Batteries three and four each have a three ampere fuse in the ground leg. This combination of fuses protects against short circuit and excessive discharge rates.

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[1]NAVSEAINST 9310.1, March 1979.

CHAPTER 2

EXPERIMENTAL

The experimental program was conducted as follows:

1. The four batteries of the pack were simultaneously short-circuited inside the "PHOTO FINISH" housing with all fuses bypassed. Voltages, currents, temperatures, and pressures were monitored throughout the run. This test was repeated three times.

2. The four batteries of the pack were simultaneously discharged at the fuse values with an external D.C. constant current power supply. For example, batteries one and two were discharged at four amperes, and batteries three and four at three amperes. Three discharges were carried out at ambient temperatures (10-25°C) and one with the buoy preheated to 71°C. Voltages, temperatures, and pressures were monitored throughout the run.

3. The third set of tests conducted was external heating of the battery pack by wrapping heat tape around the "PHOTO FINISH" unit in the vicinity of the battery pack.

Pressures were measured using a Standard Controls Model Number 1200-41-1 pressure transducer. Type K thermocouples were used to measure the temperatures at several points on the package containing the four batteries. Thermocouple location on the complete battery package and "PHOTO FINISH" housing is indicated in Figure 1. A photograph of the battery package is shown in Figure 2.

Video tapes and high speed movies were made on all tests and are on file at the Naval Surface Weapons Center, White Oak.

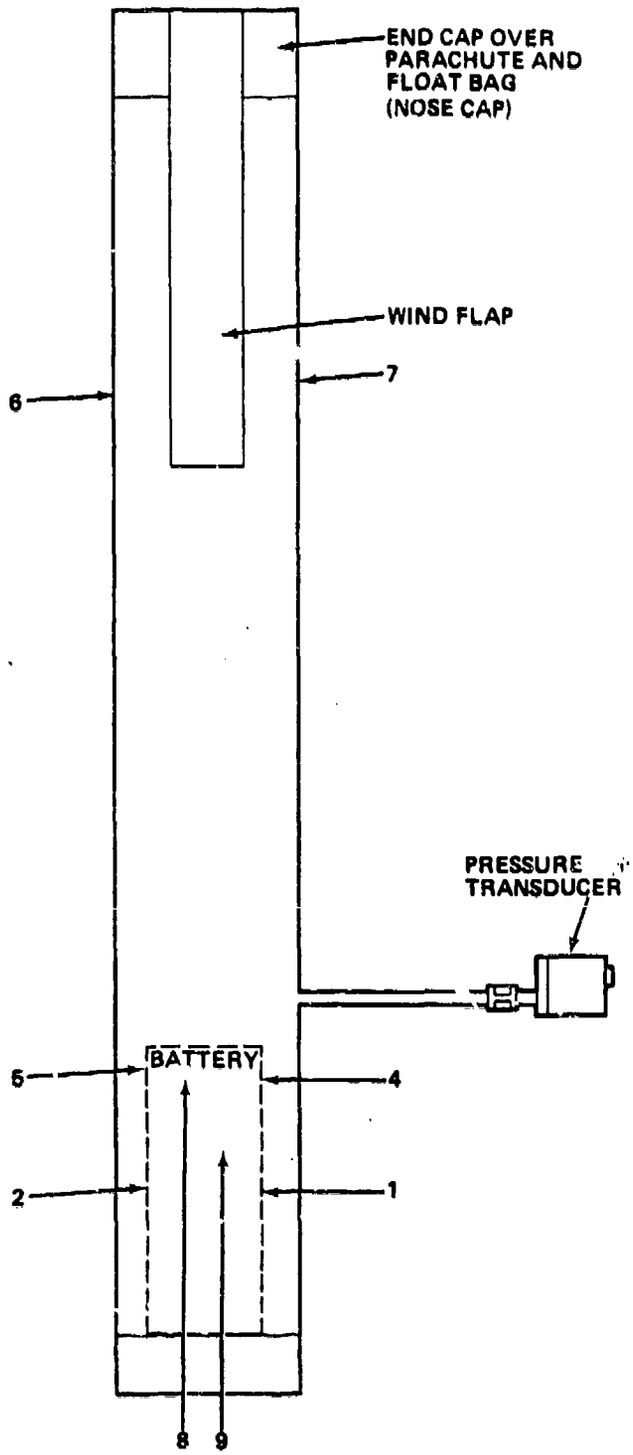

FIGURE 1 SCHEMATIC OF "PHOTO FINISH" SHOWING LOCATION OF THERMOCOUPLES AND PRESSURE TRANSDUCER AS POSITIONED FOR TEST.

FIGURE 2 PHOTOGRAPH OF BATTERY PACKAGE. THE POWER SUPPLIES USED TO POWER "PHOTO FINISH" ARE CONTAINED INSIDE THIS PACKAGE.

CHAPTER 3

RESULTS AND DISCUSSION

The first series of tests was simultaneous short-circuiting of all four batteries within the pack (all fuses bypassed) through 0.4 ohm loads. The above test was repeated three times. All three tests resulted in venting of the batteries. However, the first two tests resulted in low housing pressure upon venting. A post mortem of these units indicated that the housing leaked where the thermocouples and voltage leads exited the unit. The problem was corrected and a third short circuit test was run. The results of the third run are presented in Figure 3. Maximum pressure observed is 11 psig. The ventings caused the nose cap to be ejected at approximately 10 ft/sec. This velocity was measured using high speed photography and video techniques. After nose cap ejection the float bag inflated and subsequently bursted. A summary of the short circuit data is presented in Table 1.

The second series of tests was simultaneous discharge of the four batteries at the fuse value using four D.C. power supplies. As in short circuit, all fuses were bypassed. Batteries one and two had thirteen and four L026SH cells in series respectively. Batteries three and four each had two L032S cells in series. Batteries one and two were discharged at four amperes while three and four were discharged at three amperes. All discharges took place at room temperature except for discharge 033001 where the buoy was preconditioned at 71°C. The results are presented in Figures 4-7. A summary of the capacities observed along with the maximum temperature observed are presented in Table 2. All four tests resulted in nose cap ejection and float bag rupture. Batteries three and four were the first to vent. In all cases the venting of batteries three and four caused the housing pressure to increase to five psig. Nose cap ejection only occurred when batteries one and two vented. A summary of the pressure and nose cap ejection velocities is presented in Table 3.

The last series of tests conducted was external heating of the battery pack by wrapping heat tape around the "PHOTO FINISH" unit in the vicinity of the battery pack. A photograph of "PHOTO FINISH" with the heat tape in place is shown in Figure 8. As in the previous tests, all fuses were bypassed. This test was repeated. The results of the heating test are presented in Figures 9 and 10. External heating forced the batteries to vent and caused a nose cap ejection similar to short circuit and constant current discharge.

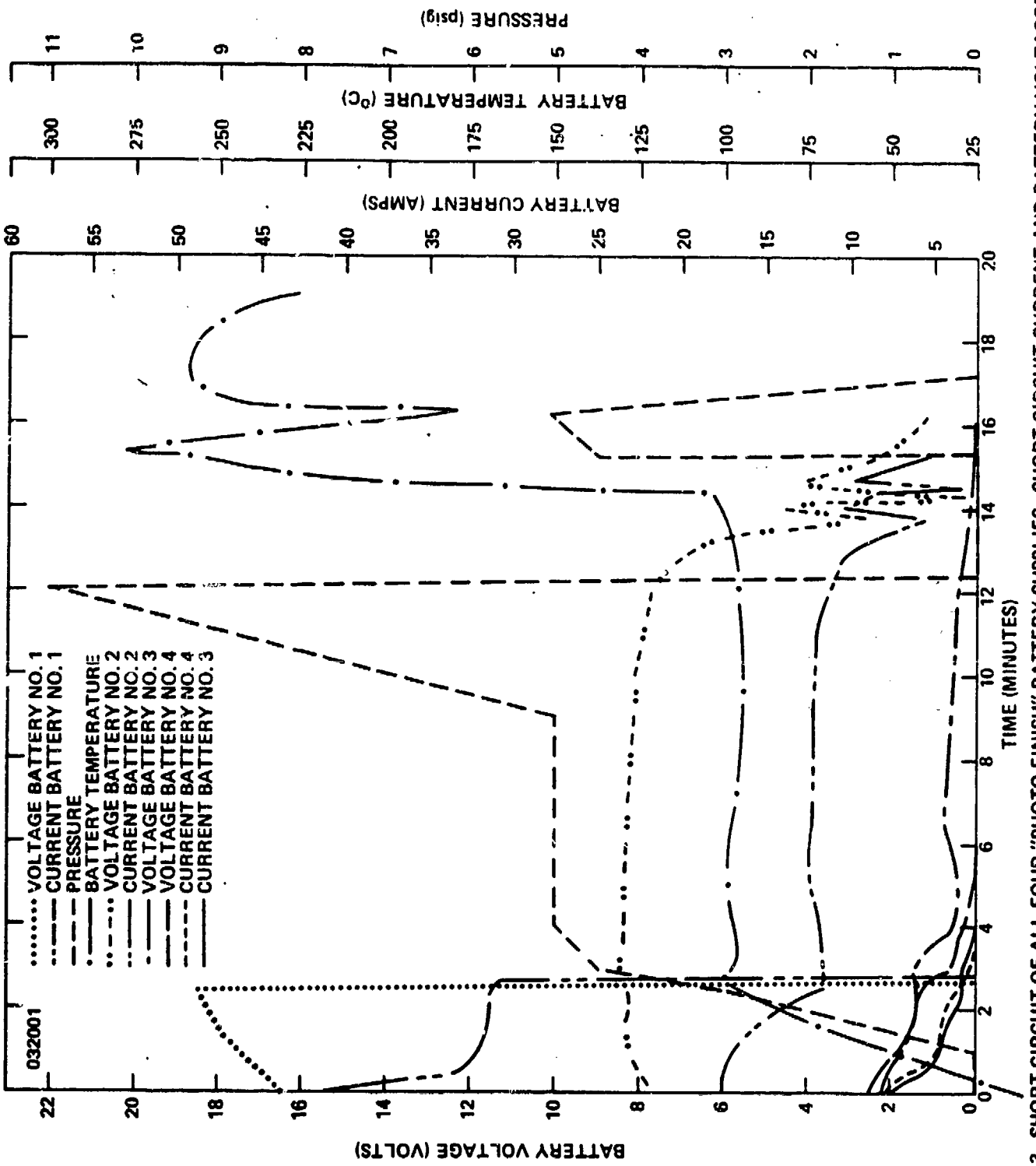

FIGURE 3 SHORT CIRCUIT OF ALL FOUR "PHOTO FINISH" BATTERY SUPPLIES. SHORT CIRCUIT CURRENT AND BATTERY VOLTAGES ARE INDICATED FOR EACH BATTERY. HOUSING PRESSURE AND BATTERY PACK TEMPERATURE ARE ALSO SHOWN.

TABLE 1 SUMMARY OF SHORT CIRCUIT DATA
ON "PHOTO FINISH" THROUGH 0.4 OHM LOAD

TEST NUMBER	BATTERY NUMBER AND MAXIMUM CURRENT				MAXIMUM BATTERY PACK TEMPERATURE (°C)
	1	2	3	4	
224001	53.4	12.2	9.0	6.2	--
224002	54.0	14.0	6.0	6.0	110
032001	40.5	17.5	7.5	7.0	267

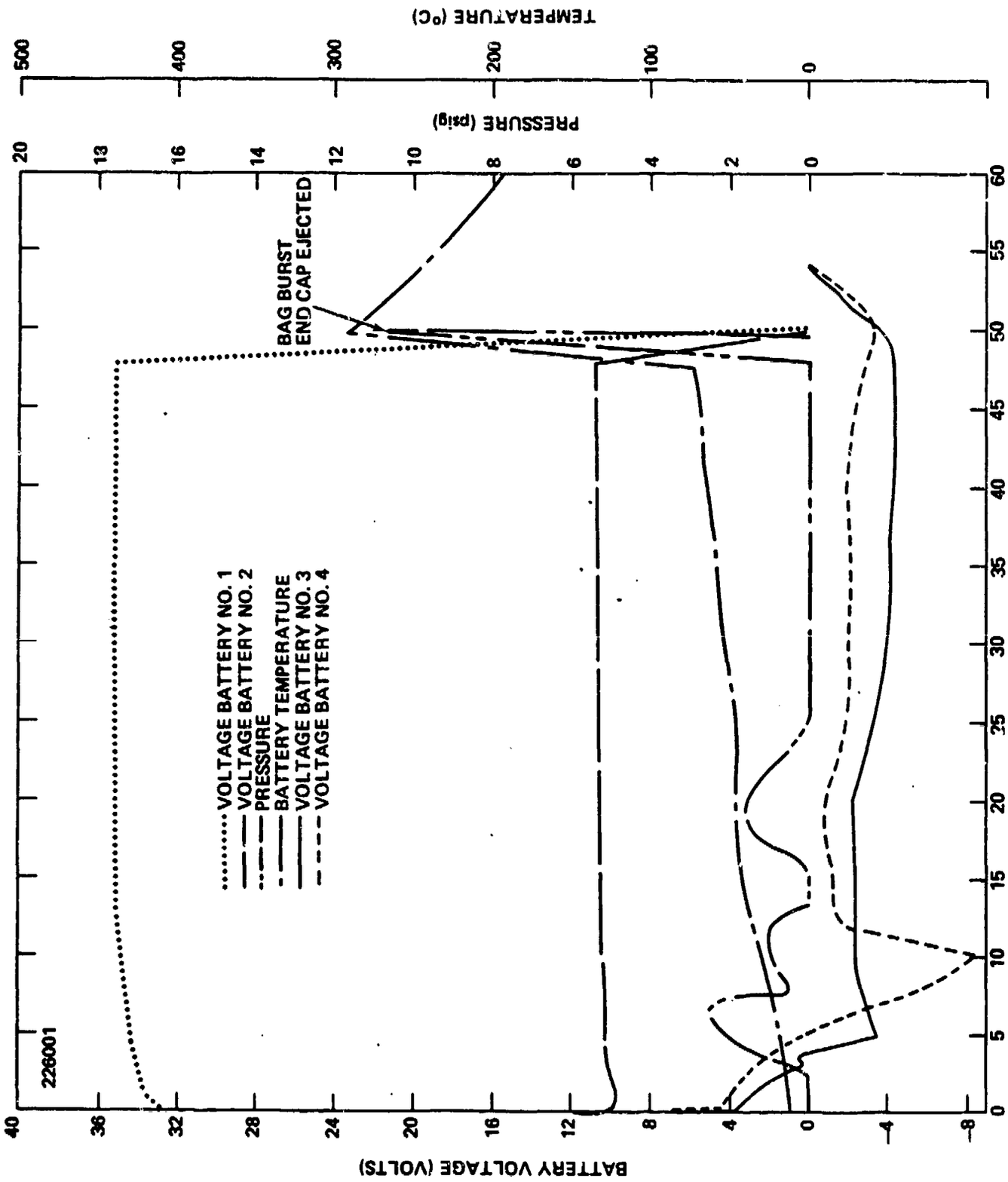

FIGURE 4 SIMULTANEOUS CONSTANT CURRENT DISCHARGE OF ALL FOUR "PHOTOFINISH" BATTERY SUPPLIES. BATTERIES ONE AND TWO WERE DISCHARGED AT FOUR AMPERES WHILE THREE AND FOUR WERE DISCHARGED AT THREE AMPERES CONSTANT CURRENT. HOUSING PRESSURE AND BATTERY PACK TEMPERATURE ARE ALSO SHOWN.

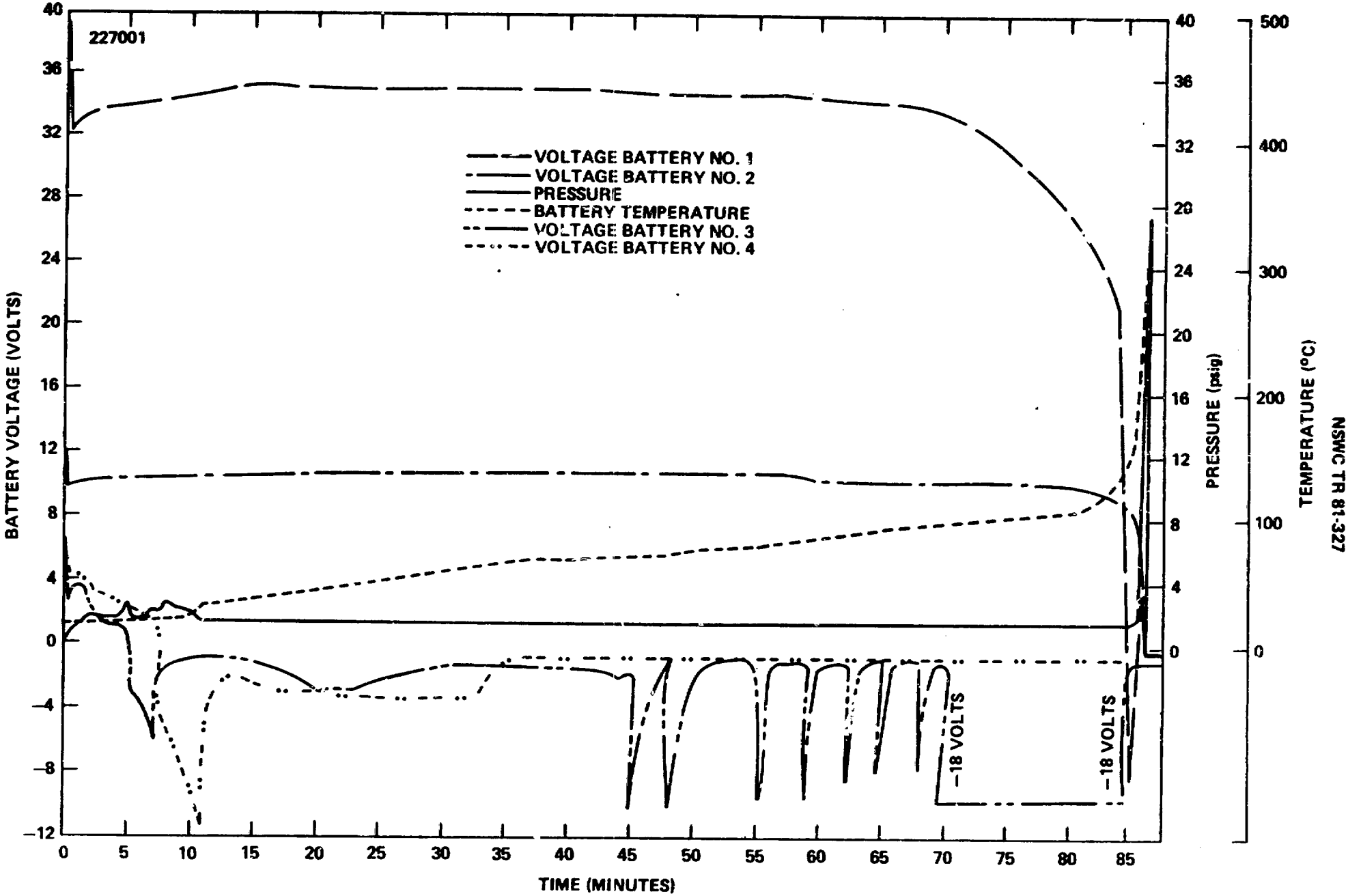

FIGURE 5 SIMULTANEOUS CONSTANT CURRENT DISCHARGE OF ALL FOUR "PHOTO FINISH" BATTERY SUPPLIES. BATTERIES ONE AND TWO WERE DISCHARGED AT FOUR AMPERES WHILE THREE AND FOUR WERE DISCHARGED AT THREE AMPERES CONSTANT CURRENT. HOUSING PRESSURE AND BATTERY PACK TEMPERATURE ARE ALSO SHOWN.

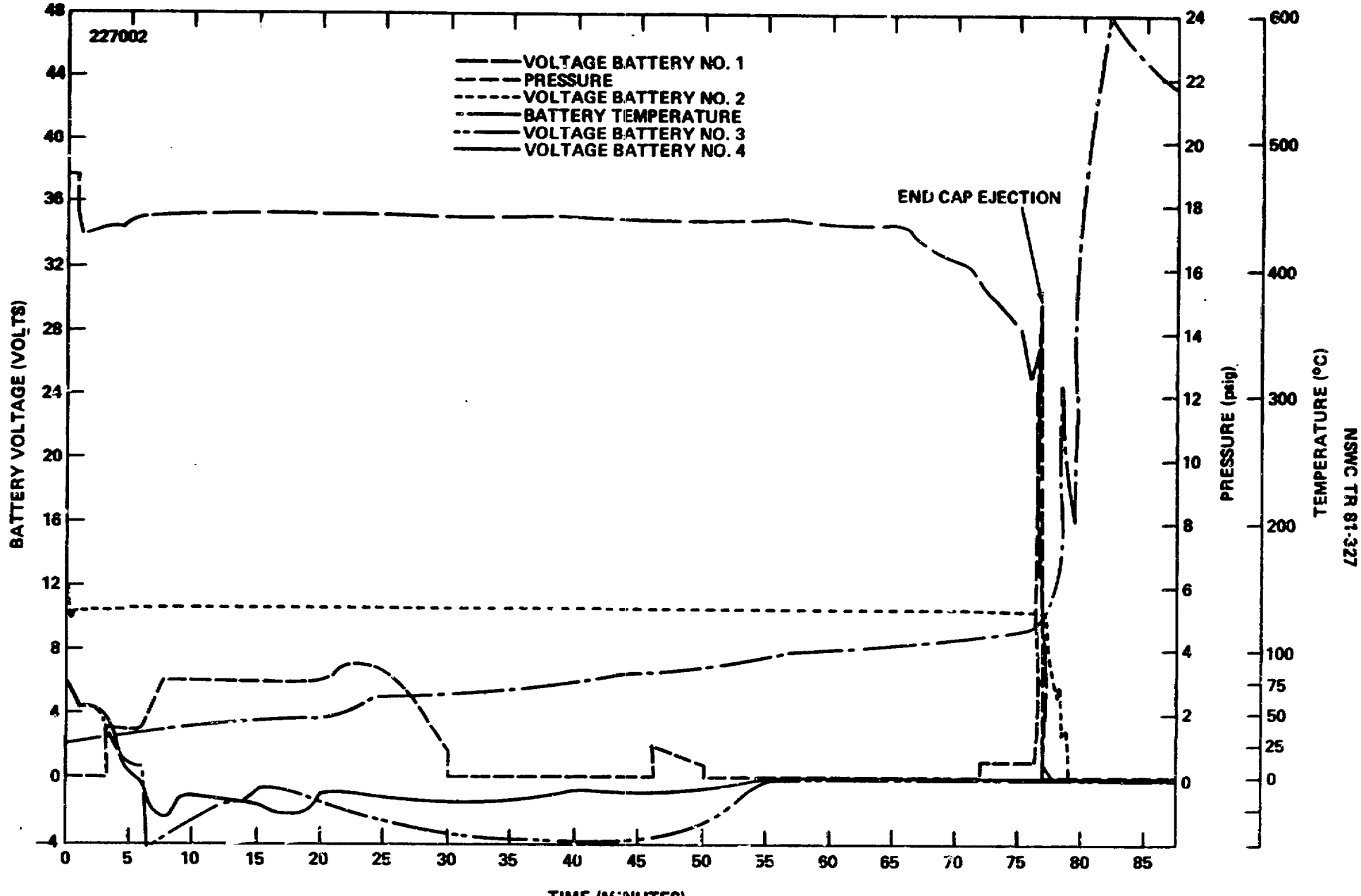

FIGURE 6 SIMULTANEOUS CONSTANT CURRENT DISCHARGE OF ALL FOUR "PHOTO FINISH" BATTERY SUPPLIES. BATTERIES ONE AND TWO WERE DISCHARGED AT FOUR AMPERES WHILE THREE AND FOUR WERE DISCHARGED AT THREE AMPERES CONSTANT CURRENT. HOUSING PRESSURE AND BATTERY PACK TEMPERATURE ARE ALSO SHOWN.

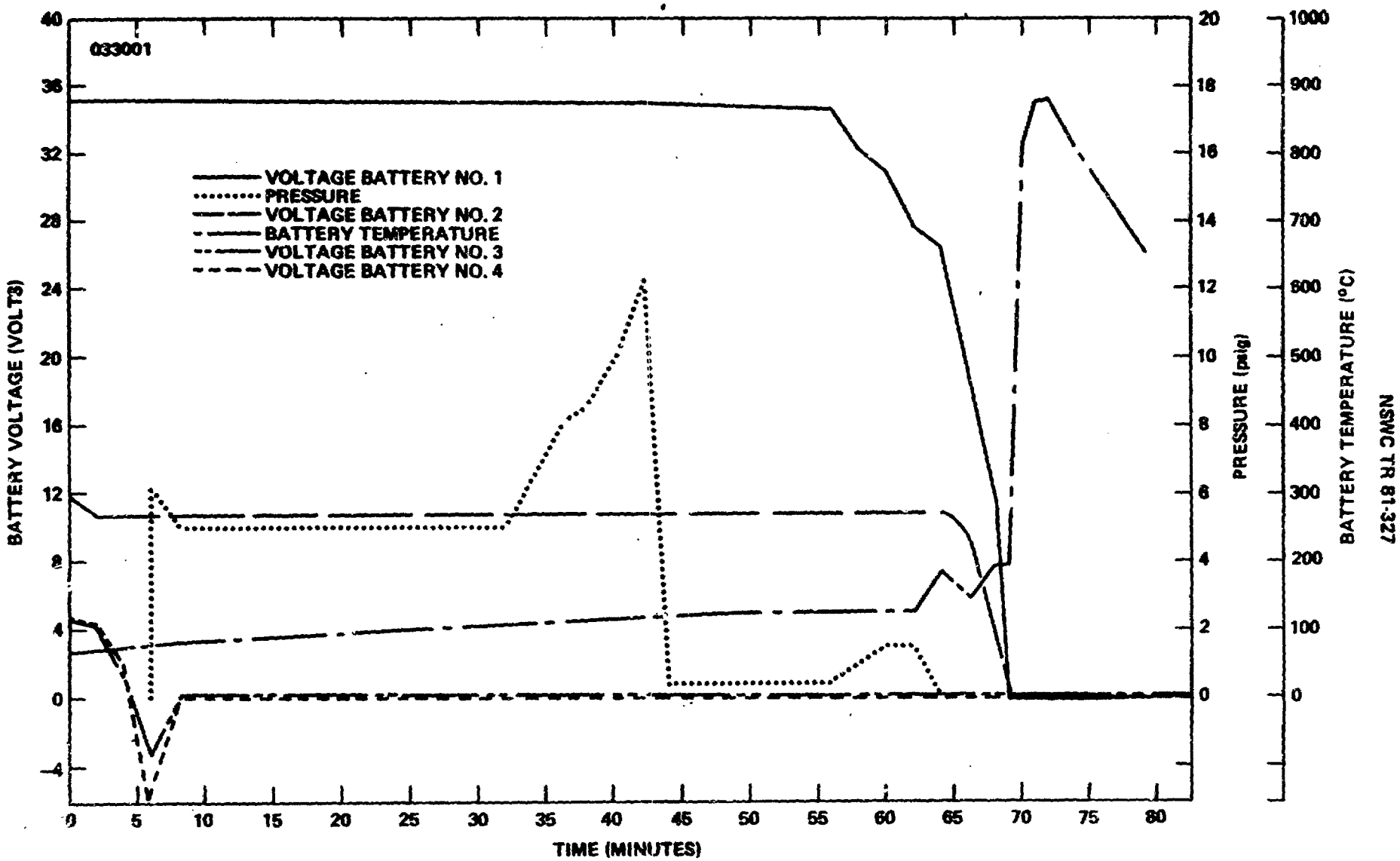

FIGURE 7 SIMULTANEOUS CONSTANT CURRENT DISCHARGE OF ALL FOUR "PHOTO FINISH" BATTERY SUPPLIES. BATTERIES ONE AND TWO WERE DISCHARGED AT FOUR AMPERES WHILE THREE AND FOUR WERE DISCHARGED AT THREE AMPERES CONSTANT CURRENT. HOUSING PRESSURE AND BATTERY PACK TEMPERATURE ARE ALSO SHOWN. THE ENTIRE "PHOTO FINISH" UNIT WAS PRECONDITIONED AT 71°C PRIOR TO DISCHARGE.

TABLE 2 CAPACITY IN AMPERE HOURS OF "PHOTO FINISH" BATTERIES TO A 2 VOLT/CELL CUTOFF

TEST NUMBER	BATTERY NUMBER AND CAPACITY				MAXIMUM BATTERY PACK TEMPERATURE (°C)
	1	2	3	4	
226001	3.05	3.30	0	0	291
227001	5.60	5.67	0.3	0.3	152
227002	5.03	5.03	0.12	0.12	605
033001	4.27	4.53	0.13	0.13	814

TABLE 3 MEASURED VELOCITY AT WHICH NOSE CAP WAS EJECTED. MAXIMUM PRESSURES ARE ALSO SUMMARIZED

TEST NUMBER	MEASURED VELOCITY (IN FT/SEC) AT 1' AND 8'			MAXIMUM PRESSURE (psig)
	1'	and	8'	
225001	--		--	23.0
226001	--		--	11.0
227001	24		20	23.0
227002	16		12	14.9
032001	10		--	11.0
032002	24		19	30.0
033001	4		--	12.0

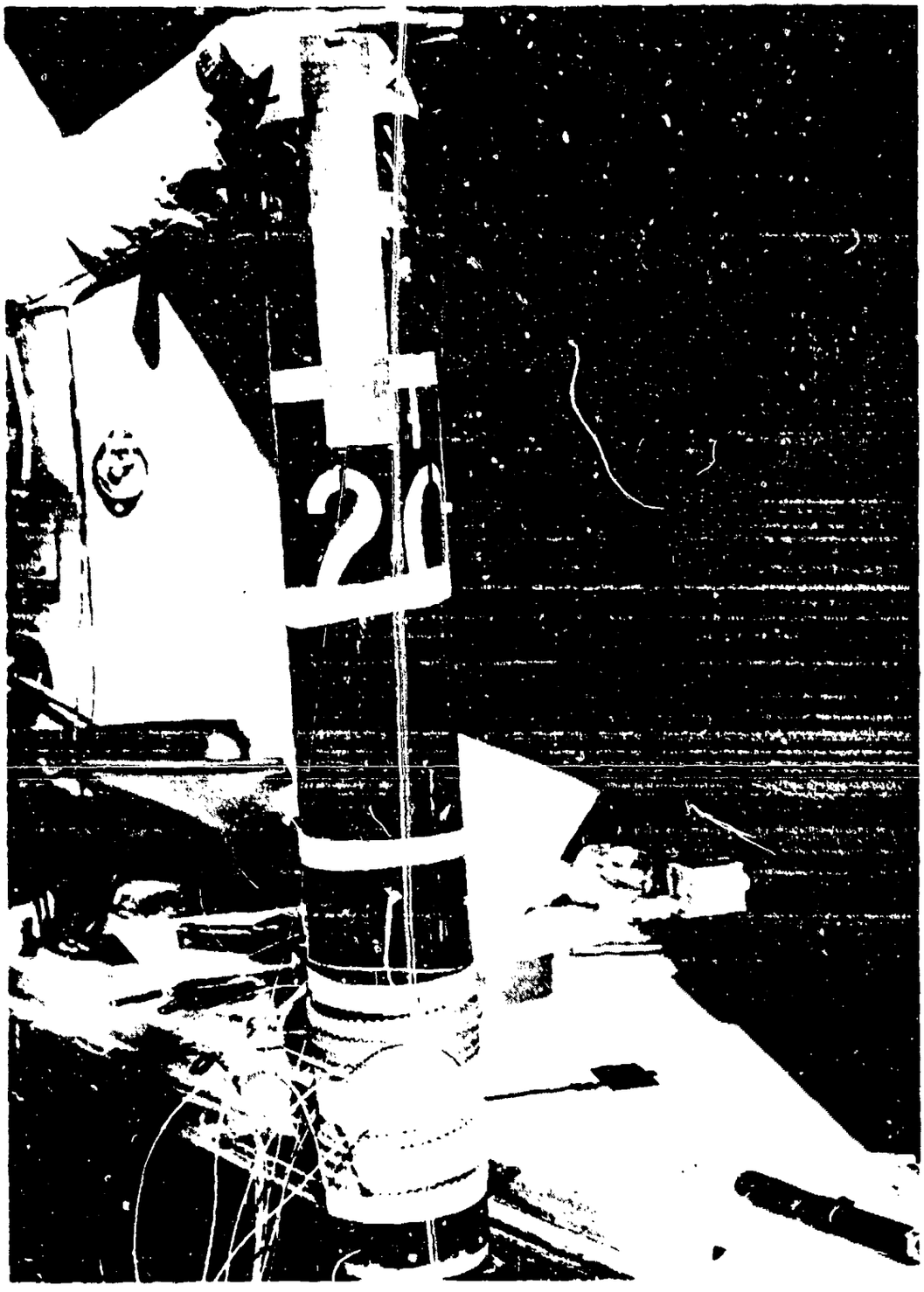

FIGURE 8 PHOTOGRAPH OF "PHOTO FINISH" UNIT WITH HEAT TAPE IN VICINITY OF BATTERY PACK

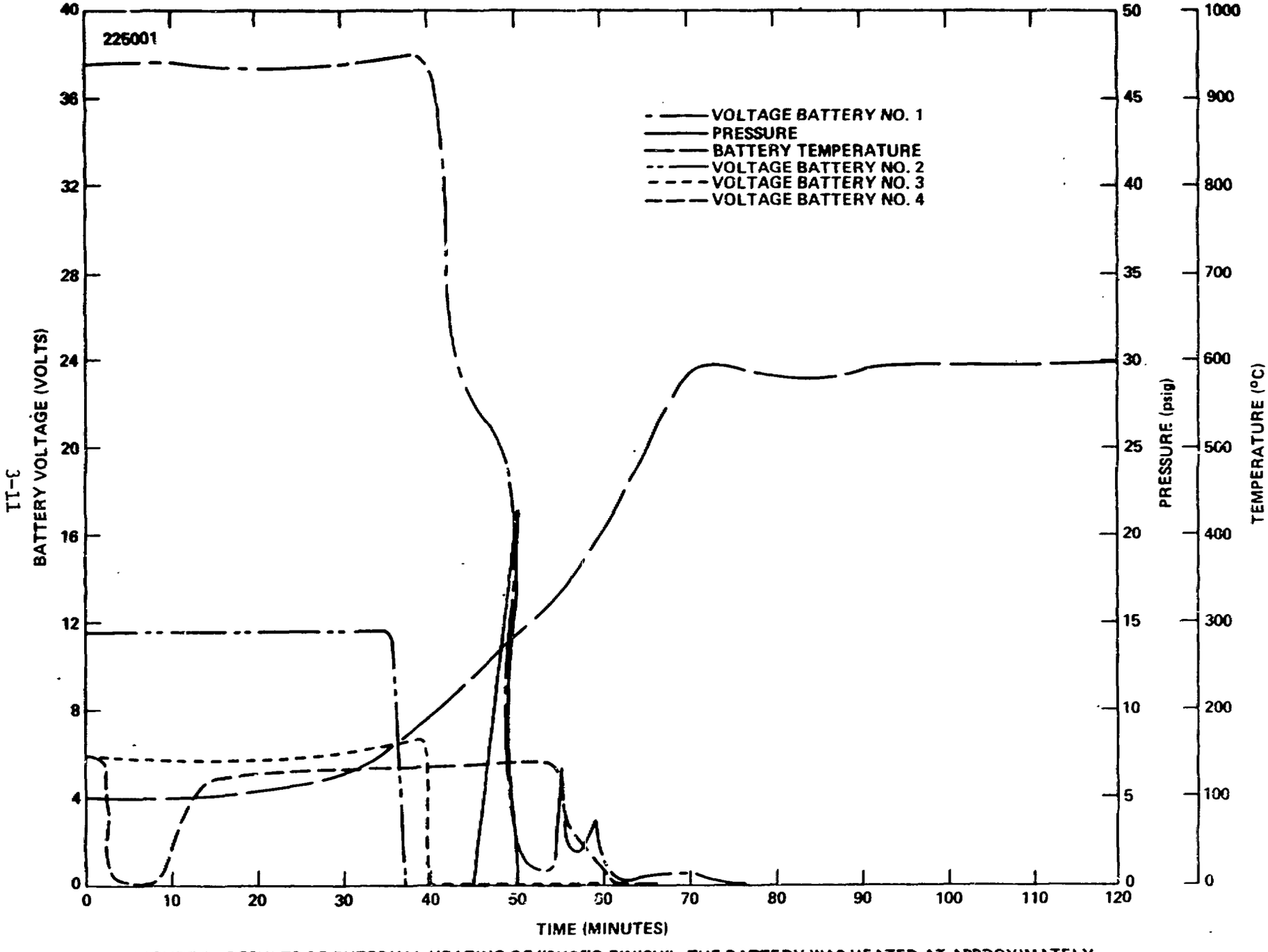

FIGURE 9 RESULTS OF EXTERNAL HEATING OF "PHOTO FINISH". THE BATTERY WAS HEATED AT APPROXIMATELY 10°C/MINUTE. BATTERY TEMPERATURE, VOLTAGES OF EACH BATTERY AND HOUSING PRESSURE ARE PLOTTED.

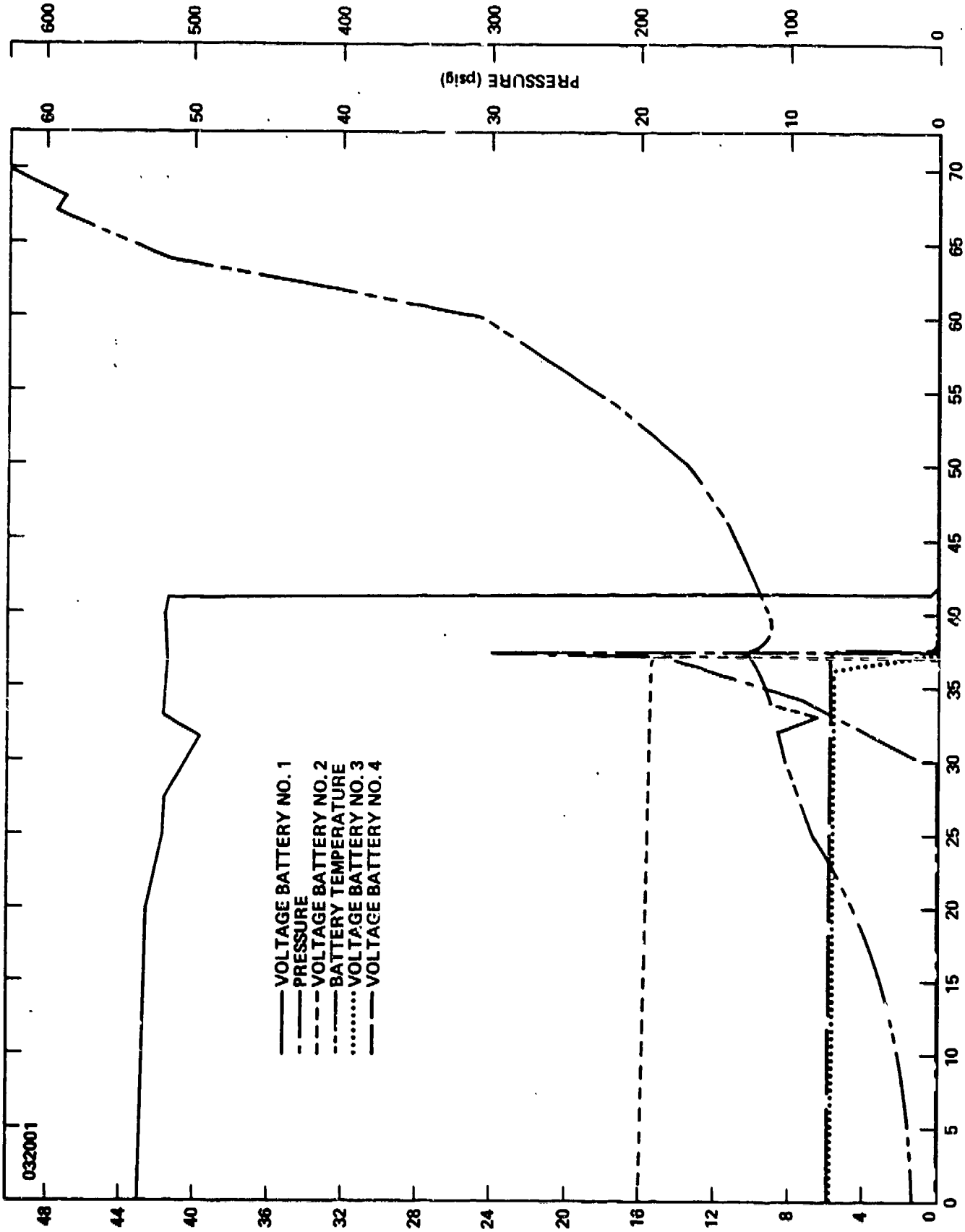

FIGURE 10 RESULTS OF EXTERNAL HEATING OF "PHOTO FINISH". THE BATTERY WAS HEATED AT APPROXIMATELY 10°C/MINUTE. BATTERY TEMPERATURE, VOLTAGES OF EACH BATTERY AND HOUSING PRESSURE ARE PLOTTED.

CHAPTER 4

CONCLUSIONS

The tests results presented in this report indicate that nose cap ejection will take place under "worst case" conditions. However, no fires were observed under any of the tests conducted.

Based upon the tests results and the scenario of use, the following recommendations should enhance the safety of "PHOTO FINISH" units:

1. Label the batteries in accordance with reference 1.

2. Reduce the three ampere fuse in batteries three and four to approximately one ampere.

3. Store batteries separately from the "PHOTO FINISH" units until ninety days prior to deployment.

4. After the batteries are loaded into the units, a CAUTION label in accordance with Figure 1 of reference (1) should be placed on both the unit and the grey overpack.

5. Do not remove units from grey overpack greater than fifteen days prior to deployment.

6. A warning notice to handling personnel should be placed on the units that after the batteries are loaded, a possibility exists for nose cap ejection.

7. The "PHOTO FINISH" units are to be loaded into the launch tubes only, and not stored inside the aircraft.

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